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ABSTRACT

This paper describes the International Futures (IFs) computer assisted simulation game for use with undergraduates. Written in Standard Fortran IV, the model currently runs on mainframe or mini computers, but has not been adapted for micros. It has been successfully installed on Harris, Burroughs, Telefunken, CDC, Univac, IBM, and Prime machines. It requires about 54K core. The global model of IFs represents the world in ten nations or regional groupings: The United States, Western Europe, the rest of the Western Developed World, Eastern Europe, the Soviet Union, Latin America (except OPEC), Africa (except South Africa and OPEC) plus the Non-OPEC Middle East, OPEC, South and Southeast Asia, and China. The issues of IFs are the rapid acceleration of global population growth, the uncertainty of food sufficiency, the degradation of environmental quality, the shortages or crises of resource (especially energy) availability, and the persistent gap between the global rich and poor. The base year of IFs is 1975. It is normally used through 2000 or 2025, although it can theoretically run indefinitely. The model, which has over 2,000 variables, has four major submodels: population, economics, agriculture, and energy. Each submodel separately represents each region. Interested readers are invited to request user manuals or equation descriptions from the author. (Author/RM)

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International Futures (IFs)

A Global Issues Simulation for Teaching and Research

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1. Introduction

This paper outlines the International Futures (IFs) global model project. It sketches the developments in the global modeling field which predate the project, and outlines and explains the general model structure. IFs is intended to be a highly transportable model which, with the accompanying manual, can be used in the undergraduate classroom. It also is intended to build structurally upon the models of the last decade so as to serve as a theory building and research tool.

1.1 Global Models

Computerized global modelling activities, especially in the area of international politics and as best illustrated by the family of models derived from INS (Guetzkow and Valadez, 1981), have been undertaken since the 1960s. A surge of development in the 1970s brought into being a new genre of world models. These models, beginning with the work of Forrester (1971) and Meadows (1972) and associated initially with the Club of Rome, have placed much greater emphasis on the global economic system defined broadly so as to include physical resource availability and environmental impacts. As opposed to the central focus of the international political models on interstate cooperation and conflict (with a more secondary emphasis on the domestic environment) the new genre deemphasizes or altogether ignores international politics (although not all international interactions) and focuses heavily upon development processes. In spite of calls for synthesis of the

two traditions (Guetzkow and Ward, 1979) and even a conference sponsored in the summer of 1980 by The Berlin Science Center to encourage dialog, little progress has been made in synthesis.

The International Futures (IFs) system is grounded fairly firmly in the more heavily economic work, but has been structured so as to provide a better basis than most such models for modeling of international political processes. This is an issue to which we will return later.

The flowering of global simulation model activities in the 1970s can be attributed in part to the relative deemphasis of Cold War and East/West issues and the increased emphasis on global issues along the North/South dimension and on global issues affecting the continued economic vitality of the North (especially energy). The heavily economic models thus encouraged benefitted from the substantial data base accumulated since World War II, the progress of economic and development theory and the daring of the early modelers who were willing to step outside of the econometric tradition and to structure models which stretched or even broke the constraints of data and theory. There is no doubt also that technological progress in the computer industry, making computer use less costly and their availability much greater, was a necessary precondition to the modeling surge. This also was felt in the international politics tradition (Bremer, 1977).

Along with the rapid increase in model numbers during the 1970s a couple of other developments were of great importance. One was the public attention garnered by the modeling activities. The skillful publicity techniques of the Club of Rome and other modeling groups and the hunger of the media and the public for a better understanding

of the "crises" of the 1970s combined to make The Limits to Growth a best seller in several countries and to give very unusual amounts of publicity to model based reports. Second, governments who were equally hungry for understanding and for policy guidance grabbed at the models. For instance the Bariloche group's Latin American World Model (Herrera, et. al., 1976) was put on the computers of the International Labor Organization and of the Institute for National Planning in Egypt (and probably many other places), the Leontief world model (1977) was commissioned by the United Nations and indirectly provided projections to both the World Bank and to the U.S. government's study Global 2000 (1980). SARUM (SARU, 1977) was used heavily by the OECD in the preparation of the Interfutures report Facing the Future (OECD, 1979). The World Integrated Model (WIM) or the second generation Mesarovic-Pestel model (Mesarovic and Pestel, 1974; Hughes, 1980) was installed on the computer of the USDA, of the Plan and Budget organization in Iran and of the Institute for National Planning in Egypt (and quite a number of other places).

1.2 The Lessons of the 1970s for World Modeling

The experiences of the 1970s should certainly be searched for lessons before world modelers proceed too far into the 1980s. A number of lessons are implicit in the above discussion (we focus here on the negative lessons, not the positive).

First, there remains the task of building a bridge between the two modeling traditions. Models are, of course, simplified representations

of real world systems and we should not broaden the scope and complexity of models merely because of a vague sense of lack of closure. Each model is directed at certain questions and cannot productively be used for others. In many cases models need not be expanded. There is, however, a set of important interactions between the conflict/cooperation and development dimensions in world politics which do cry out for a joint treatment. The political environment of the 1980s, including the warming up of the Cold War and its greater definition in terms of resource and economic issues, will almost certainly reinforce the perception of need for joint treatment.

Second, the experience of policy makers with the models has been rather frustrating. One key problem is that the models are very highly aggregated, an inevitable result of their global scopes and relatively long time horizons. Since the models for the most part represent regional groupings rather than individual nation-states, and since they contain few real "policy" variables, they have supported little real policy analysis. A related factor is that the models contain a large number of key assumptions which, when varied, allow production of a vast range of futures or scenarios. Policy analysis requires narrowing of alternatives at some point, not broadening. In view of these characteristics it is not surprising that the international organizations have found the models generally more useful than national governments have. For the IO lack of nation-state specificity may actually prove a blessing. One of the interesting characteristics of interaction between policy oriented users and the models has not been the ability of the users to derive specific policy recommendations but rather their considerable

increase in understanding of the systems impacted by their policies.

Third, the models have raised a storm of scientific controversy. The relative paucity of theory and data upon which to build them has forced a relaxation of model building criteria, especially in validation. Critics have charged that this relaxation and the aura of science which inevitably attends a computer output for a significant portion of the public constitute an especially unfortunate combination. Supporters counter that the effort is largely one of the theory building and that the models are invaluable aids to thinking and understanding for those who use them. Yet it must be realized that models, no matter how well validated and explicitly based in theory, are inevitably inaccurate representations of reality because inaccuracy is inherent in their simplification of the world. And the less validation and more speculation about relationships they incorporate, the greater the error. World model structures inevitably incorporate philosophical perspectives and normative biases. Unfortunately these have not been made as clear to users as they could be. Moreover the dialog among modelers themselves has been inadequate to elucidate the ways in which fundamental perspectives become engrained in model structures.

1.3 The Aims of IFs

Clearly, the problems inherent in the above lessons are sufficiently fundamental that no modeling effort will succeed in eliminating them. The International Futures (IFs) model does not. But we will most likely see a new generation of models in the 1980s which build upon these earlier lessons.

IFs does so in several ways. First, the model structure, although not yet incorporating significant international interaction representation, does seek to provide a foundation for its further development. For instance three nation-states, the U.S., the U.S.S.R., and China, are represented individually rather than being embedded in larger regions. Second, the model is directed primarily at educational use and not at policy analysis. This does not mean that it has no policy relevance or even that it has less than other models. It is instead an admission that such models are best suited to look at the impact of general policy directions; attempts to structure them so as to allow specific policy analysis requires considerable elaboration in relevant submodels and often leads to an imbalance in detail levels of the model. Moreover, a model structured for educational use must direct more development attention to the overall closure of the system and to careful attention to behavior under extreme assumptions. Since the model will be used by a wide range of students rather than a handful of highly knowledgeable experts, less ability to compensate for model weaknesses can be assumed. This attention to system completeness and behavior across a wide range of inputs is also desirable scientifically.

Third, the model does not attempt to rebuild the wheel. It draws heavily upon the hopefully best characteristics of many prior world models. Because the author was active for many years in the development of the World Integrated Model, that model was used especially heavily, but SARUM World 3, Bariloche and Leontief model features were also incorporated. Global model building must become a cumulative effort

if it is ever to achieve the character of a science implicit in the wise old saying that a science is a field in which any fool of one generation can go beyond the geniuses of the previous generation.

Fourth, the IFs project seeks to identify the ways in which fundamental perspectives, such as political economy positions, become embedded in the model structure. These must not only be made clear to the user, if at all possible, but insofar as possible the user should be able to represent within the computer model other fundamental perspectives.

Finally, with a few exceptions (especially World 3 and SARUM) world models have been inadequately documented. IFs has documentation at two levels which are continually revised as the model changes. The first is a user's manual which instructs in use, provides exercises, outlines model structures, and discusses the problems of fundamental perspectives embedded in model structures. The second is a description of equations aimed at technically knowledgeable users and other model builders.

In order to understand IFs, however, we must turn our attention directly to it.

2. IFs Structure

Those who want more detail on the model structure than can be provided here are directed to the user manual and technical equation description. Here we can only present the general scope of IFs concerns and an outline of the structure.

2.1 General Concerns

A model is shaped by the issues to which it is directed. The issues of International Futures (IFs) are primarily those which the Club of Rome named the "problematique." These have included the rapid acceleration of global population growth, the uncertainty of food sufficiency, the degradation of environmental quality, the shortages or crises of resource (especially energy) availability, and the persistent gap between the global rich and poor. Any such list is inevitably a subset of the concerns of potential users. Human rights is conspicuously absent, and is the treatment of inequality within countries as opposed to between them. So too is missing the cold war issue, although again, as we shall see below, the separate representation of three critical states and of governmental expenditures including military spending, provides a basis for future development. In fact, in a preliminary version of IFs, installed at the Science Center in Berlin, a very simple action/reaction model for military expenditures was incorporated, with full feedback to other model subsystems.

Perhaps the most unique feature of IFs, however, is the attempt to allow the user to impose major change in fundamental perceptions upon the model. Specifically the model structure and user manual description outline two dimensions of perspective. The first is political economy. A radical world model, as stressed by the Bariloche group, should differ from an internationalist mode and even more from a classical liberal world model. These differences, of course, are both descriptive with respect to the way important systems actually work and prescriptive with respect to how they should work. Structural difference in the described systems should be identified and IFs should contain switches,

insofar as possible,which move the system from one perspective to another. In reality this is very difficult to do for two reasons. First, the differences in these perspectives (or paradigms, as they are sometimes called) are not sufficiently well identified. Second, even to the extent that they are, the differences often fall at a level of analysis which differs from that represented by model variables. For instance, some key differences lie in micro-processes such as the nature of deal making between unequal parties. These can only be represented in a macro level model like IFs by focusing on secondary consequences, such as whether foreign aid helps the recipient region or injures it.

Nevertheless some important distinctions among political economy perspectives have been identified within IFs and the user can change assumptions. The second dimension of important perspective differences identified in the IFs project is labelled political ecology. By analogy to political economy this dimension structures paradigms which focus on the descriptive and prescriptive images of the relationship between political/social systems and their larger economic and bio-physical environments. One can identify at one end those who believe that human systems pose no significant threat to biological and physical systems, and that the latter in turn will not significantly constrain the human systems. They believe that any political threats or constraints will be overcome by adaptations in the human systems and by technological control over the environment. These people might well be labelled "modernists" and are well illustrated by the work of Herman Kahn (1976). At the other end are those who perceive imminent and unavoidable threats

and constraints from the biophysical system to the human systems and vice versa. These individuals might be labeled neo-traditionalists and are illustrated by Meadows (1971). Because world models grew up in the 1970s in large part in response to differences of opinion on this dimension, it is easier to represent by switches within the model than is political economy.

The rather dramatically different futures which can be represented with IFs are one reason for the name and acronym. The model facilitates complex if-then statements about the future. And depending upon the fundamental perspectives there are a great number of possible futures, hence the plural use. This inability with IFs to outline a definite future, or even a category of similar ones, shaped by a basic orientation, can make IFs frustrating to use. The philosophy of the IFs project, however, is that it is better for students and other users to understand the bases for our inability to predict, and even to be frustrated by it, then to falsely accept any model as a scientific tool for divining the future.

2.2 Specific Features of IFs

The IFs system is written in standard Fortran IV and structured to be as portable as any quite large model can be. There are actually two basic elements of the IFs system, the model itself and a software package in which it is embedded. The software package handles interactive communication with the model. A user has a number of commands available to control model use. Of greatest importance are five: PAR and SERIES which when used with variable names and values allow changing of data input; RUN which executes the model; PRINT

and PLOT which structure tables and graphical ouptut resulting from a model run. Detail on use of the command language is included in the user manual.

The global model of IFs itself represents the world in ten nations or regional groupings: the United States, Western Europe, the rest of the Western Developed World, Eastern Europe, the Soviet Union, Latin America (except OPEC), Africa (except South Africa and OPEC) plus the non-OPEC Middle East, OPEC, South and Southeast Asia, and China. As with issue coverage, no regionalization can be completely satisfactory. Additional regions are generally desirable but carry the costs of additional computer space and model complexity. Least desirable are regions like the Rest of the Western Developed World, which lumps geographically and economically very different countries or South and Southeast Asia, which is too large and diverse an area to be put in a single region.

In most cases, however, region members are geographically contiguous, at a similar level of economic development, and share somewhat similar resource availabilities, cultural patterns and a sense of regional membership. As mentioned above IFs does separately represent the United States, Soviet Union and China. Thus some East-West issues can be considered in the current structure, and the potential for greater development of them exists.

Temporally, the base year of IFs is 1975 and the model has a one year cycle time. The model is normally used through 2000 or 2025, although it can theoretically run indefinitely. The model structure is fully recursive, avoiding any simultaneous solutions. Thus it runs fairly fast.

The model has over 2000 variables which are accessible for input and output by the user. Perhaps an equal number are involved in intermediate calculations but cannot be changed or seen by the user. The model has four major submodels: population, economics, agriculture and energy. Each submodel separately represents each region.

Figure 1 indicates the overall structure of IFs. All regions have the same basic structure as example regions M and N. The linkages among regions are trade (in the categories of the economic submodel) and foreign aid. Investment flows will be added. Within each region it is possible to conceptualize three levels (as in the multilevel, hierarchical structure of the Mesarovic-Pestel model). At the lowest level is the biological-physical environment in which such variables as land availability and resource levels are represented. Above this is the demographic-economic-technological system level with the bulk of the four submodels. And at the top level are socio-political systems which are not represented explicitly in IFs and which the model user must consciously introduce into the model.

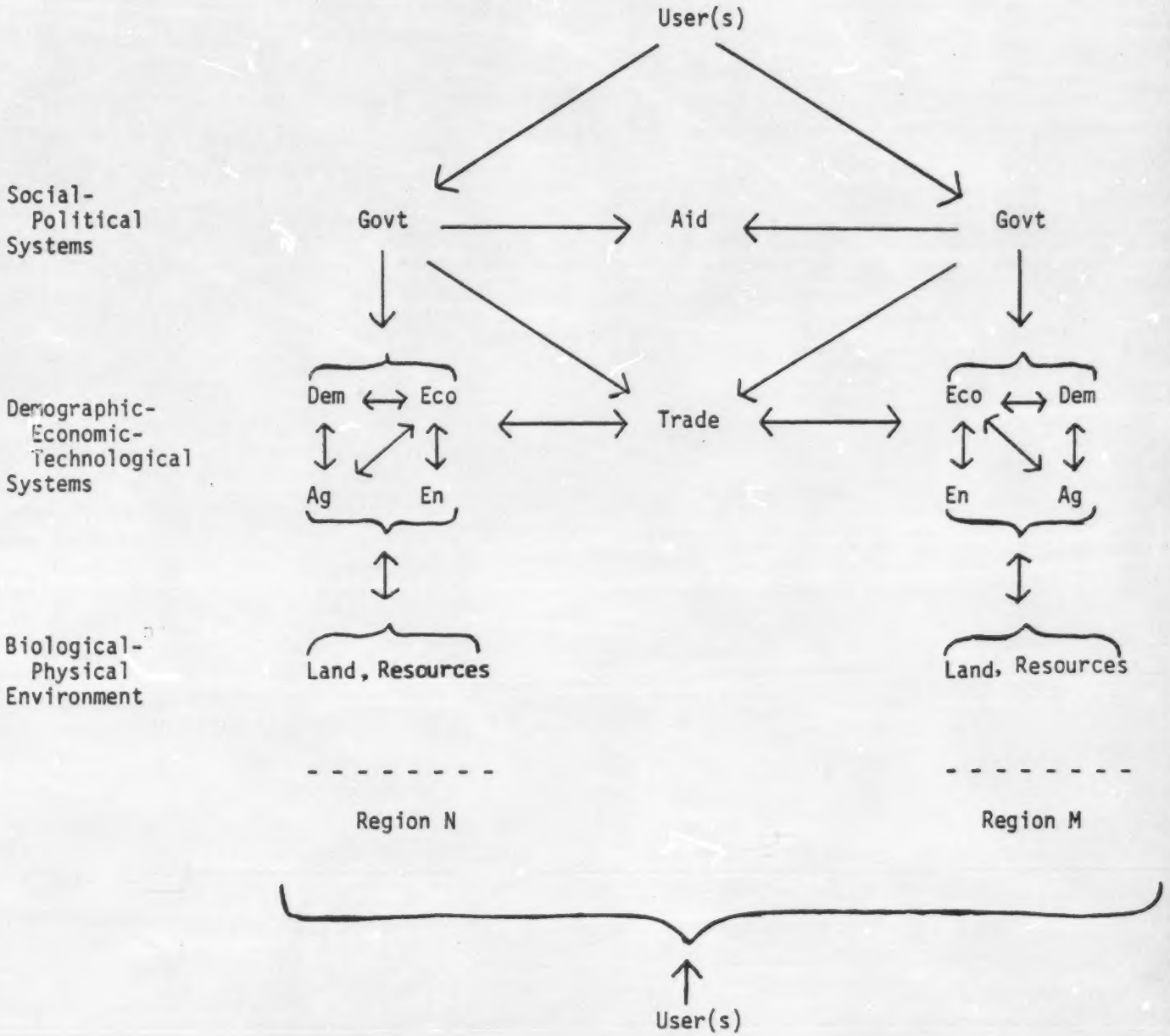
In the most general terms, political-economy debates center on the linkages between the top two levels, while political-ecology differences revolve around linkages between the lowest level and the higher ones. Those perspectives do, of course, also say much about structures within individual levels and among regions.

The user of IFs can simply let the system evolve over time; it is self-contained. The user can also, however, intervene in three major ways:

1. By specifying government policies.
2. By changing values of basic parameters such as level of

Figure 1

CONCEPTUAL FRAMEWORK OF SUBMODEL INTERRELATIONSHIPS



resource availability.

3. By altering the structure of relationships among variables. This is important in shifting paradigm perspectives. For instance, for an internationalist, foreign assistance will improve the recipient's economic growth rate -- for a radical it will not.

The government level is not yet a full submodel but will gradually evolve into one. Currently, it consists of a set of policies which fall roughly into four general categories:

1. Legislation/regulation, such as family planning programs.
2. Government expenditures, both level and pattern (health care, education, military, foreign aid).
3. Taxation/redistribution.
4. Foreign policy, incorporating cooperative and conflictual behavior (not yet implemented).

The Population Submodel. The population submodel relies upon the cohort component analysis technique. It represents five-year cohorts in each of three distributions: age, fertility and mortality. In each year a product of the fertility and age distributions provides total births, which enter the age distribution at the bottom. Products for each cohort of numbers and mortality rate provide deaths and reduce cohort size. One-fifth of each age group moves up into the next in each year. Crude birth and death rates are computed from the distributions. Physiological caloric requirements are computed from the age distriubtion and another representating age specific requirements. When the caloric requirements are compared with calorie availability

(from the agriculture submodel), starvation deaths can be computed.

The fertility and mortality distributions change over time is response to income per capita, income distribution and scenarios or exogenous representations of change from all factors not explicitly represented (e.g. family planning programs).

Average life expectancy at birth, literacy rate, and the physical quality of life are represented. This latter measure is computed the same way as that of the Overseas Development Council. Among the variables computed in the population submodel which have great importance for other submodels are, of course, total population size and labor force size.

The Economic Submodel. The economics submodel of IFs is an economic equilibrium model, although the supply side factors tend to dominate the long term dynamics. It has the same structure for each of the regions. Although there might well be reason to represent the communist countries differently the economic submodel is so highly aggregated that the distinction between free market economy and centrally controlled economy (which itself overstates real world differences) is not terribly important. The model is in fact a representation of a kind of mixed economy.

The economy has five sectors: agriculture, raw materials, energy, manufactures and services. The heavy emphasis on the primary sectors is consistent with the emphasis of the model as a whole. In fact the agriculture and energy submodels represent primary sectors by and large, and computations of those submodels override and replace many of those in the two sectors of the necessarily simpler economic submodel.

The supply side distinguishes gross production, which is computed using a Cobb-Douglas function with disembodied technological progress, and production remaining to satisfy final demand after satisfaction of intersectoral flow needs. These latter depend upon an A matrix, although currently the structure is of minimal importance for lack of data and a dynamic mechanism for A matrix change.

The demand side computes private consumption, government consumption and investment by destination in the same categories as on the supply side. In addition government expenditures are computed in the more traditional destination categories (military,education, health and foreign aid).

Imports and exports, in the same five sectors, respond to demand and production levels in the sectors, and also to relative prices of the goods or services categories across regions. In addition shortages of foreign exchange constrain imports.

Supply and demand are balanced using stock levels as a buffer for short-term imbalances. Stock levels (and input cost changes) alter prices and investment patterns. Shortages of basic inputs (e.g. energy) constrain production below full production levels.

The Agriculture Submodel. The agricultural submodel of IFs has a general structure very much like the economic submodel. Because both agricultural and energy submodels are intended to supplant appropriate sectors in the economic submodel, such similarity is necessary. More specifically, the agricultural submodel has distinct demand and supply sides, with equilibrium between the two pursued over time and stocks serving as a buffer. Agricultural demand is a function primarily of consumer income levels and prices. Demand is calculated

separately for crops and meat/fish. Supply is also calculated in the two categories and is a function primarily of land, capital inputs, labor, and prices. Land is represented in five categories: crops, grazing, forest, undeveloped, and urban.

On the supply side yield has decreasing marginal returns to fertilizer and other inputs. Although stock levels normally determine prices, users can set them exogenously. Agricultural demand has three components: food, industrial use and livestock feed. Food demand is based on the total consumption expenditures (in turn based on an Engel's curve) in the economic model.

The Energy Submodel. The energy submodel of IFs, like the economic and agricultural submodels has distinct demand and supply sides with equilibrium pursued over time. Energy demand is a function of economy size, prices and exogenous conservation assumptions. Supply is computed in four categories: oil and gas, coal, renewable (solar, geothermal), and nuclear. Supply depends on capital stock invested on each energy type and is constrained by resource availability.

Trade in energy is parallel to that in the economic submodel and in agriculture. Of course, possible constraints on exports (e.g. from OPEC) are represented at the option of the user.

Both ultimately discoverable and exploitable resources and known reserves are represented in IFs. These are critical variables in model dynamics.

3. The Project Schedule

The above description of IFs is necessarily much abbreviated. The interested readers are invited to request user manuals or equation

descriptions from the author.

The IFs project was begun in the fall of 1979 as a two year project. The time schedule for the project has been as follows:

April 1, 1980	Completion of basic model structure in four issue areas and of interactive software.
June 1, 1980	Completion of first-generation model and software for transfer to other computer systems and completion of a short manual to facilitate transfer. Beginning of transfer to a few test sites for the Fall, 1980.
August 1, 1980	Completion of first draft of student manual.
September 1 - December 31, 1980	Testing and revision of model and manual at selected initial test sites.
January 1 - June 1, 1981	Testing of revised model and manual at additional test sites and preparation for widespread dissemination.
July 1, 1981 +	Open dissemination of model and manual.

The project is on schedule and the second round of testing is currently underway. Any reader who wishes to particpate in the testing this spring or who would like a copy of the model next fall when open dissemination begins should contact the author. The model currently runs on mainframe or mini computers, but has not been adapted for micros. It has been successfully installed on Harris, Burroughs, Telefunken, CDC, Univac, IBM, and Prime machines. It requires about 54 K core.

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